Preliminary Geology and Related Economic Mineralization Potential of the Chéticamp Area, Cape Breton Island, Nova Scotia

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Introduction

The Chéticamp area of western Cape Breton Island, Nova Scotia, is located in the Aspy terrane, an area considered in regional paleo-reconstructions to be part of the microcontinent of Ganderia (Fig. 1). Rocks in the Aspy terrane are mainly Ordovician-Devonian metavolcanic, metasedimentary and plutonic rocks (Lin *et al*., 2007). However, granodioritic and granitic rocks of the Chéticamp Pluton are Late Neoproterozoic, based on poorly constrained Rb-Sr and U-Pb ages (Barr *et al*., 1986; Jamieson *et al*., 1986), an age which is not typical of the rest of the Aspy terrane. Recent work by Slaman (2015) confirmed these older ages but also showed that other plutonic units in the Cheticamp Pluton ranged in age from Cambrian to Devonian, and hence the term Chéticamp Pluton needs to be abandoned. Furthermore, the contacts of the plutons are mainly faults, and hence their relationship with the adjacent Jumping Brook Metamorphic Suite is uncertain (e.g. Barr *et al*., 1986, 1992; Jamieson *et al*., 1989; Tucker, 2011).

With better age controls, combined with detailed mapping and modern geochemical techniques, interpretations of the petrology and tectonic setting of these plutonic units are now better understood

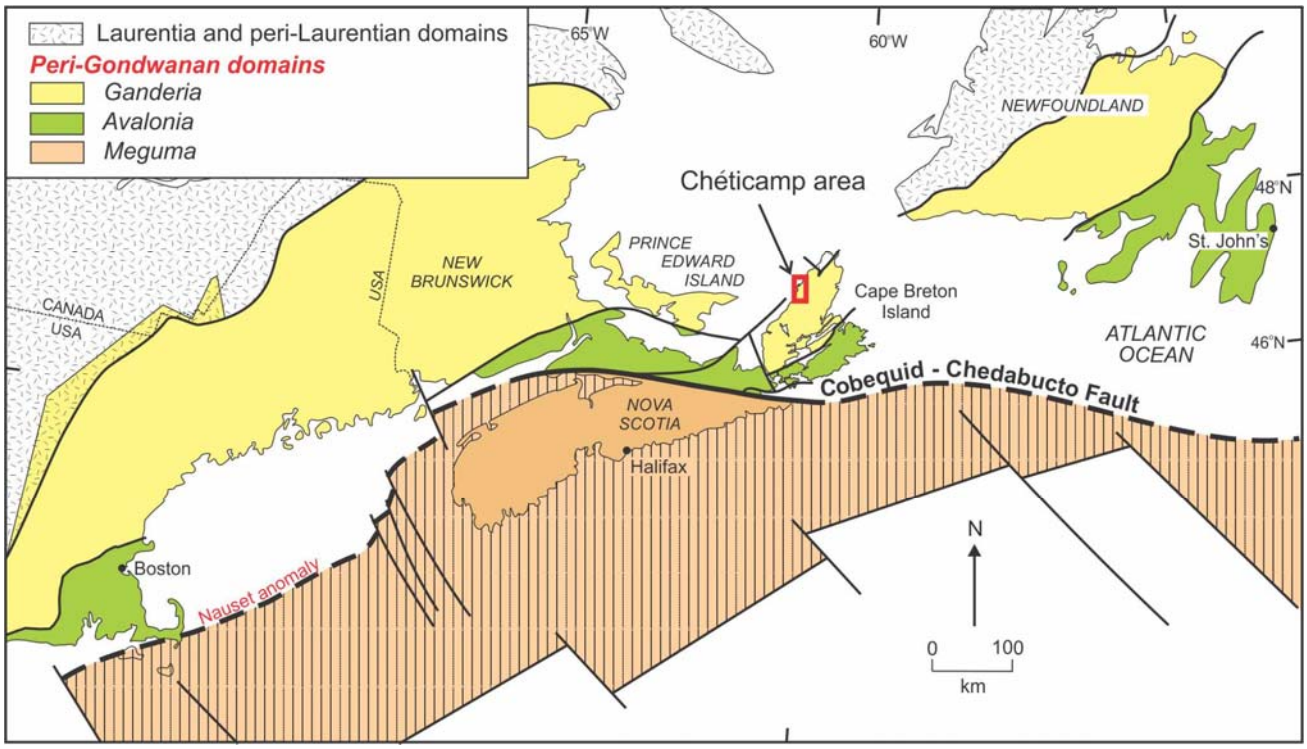

Figure 1. Map of the northern Appalachian orogen after Hibbard *et al*. (2006) showing the location of the study area (red box) in Ganderia of western Cape Breton Island, Nova Scotia.

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and part of an M.Sc. thesis at Acadia University by the second author (L. Slaman). Some preliminary results of her work are included here.

In addition, this area has been an economic mineral exploration target since the 1890s, with the discovery of Zn, Cu, Pb, Fe, As and Au in the Jumping Brook Metamorphic Suite (e.g. Sangster *et al*., 1990 and references therein). Recent work has further shown the presence of significant Cu and Ba mineralization in both the plutonic units and the nonconformably overlying Devonian Fisset Brook Formation (e.g. Slaman *et al*., 2014).

Purpose of Study

The current geological understanding is that rock types in the Faribault Brook area include metasedimentary rocks, mafic and felsic metavolcanic rocks, amphibolites and varied gneissic and plutonic rocks, with ages ranging from Late Neoproterozoic to Devonian (e.g. Jamieson *et al*., 1989, 1990; Lin *et al*., 2007; Tucker, 2011; Slaman, 2015). It has been suggested that these rocks and others in western Cape Breton Island may correlate with those in parts of Ganderia in central Newfoundland and New Brunswick (Fig. 1), which host important economic mineral deposits (e.g. Barr *et al*., 1998; van Staal, 2007; van Staal *et al*., 2009). In order to further investigate these possible correlations, more detailed studies of field relations, rock types, geochemistry, geochronology and tectonic setting are needed in western Cape Breton Island, and hence this project was initiated in 2014.

Field Relations

Introduction

Geological mapping at 1:10 000-scale in the western part of Cape Breton Island, in an elongate area about 10 km wide that extends from French Mountain and the Cabot Trail in the north to Northeast Margaree River Fault to the south (Fig. 2), was started during the summer of 2014 (Slaman *et al*., 2014; Slaman 2015). Based on the new mapping combined with the earlier work of Barr *et al*. (1986; and related unpublished data), Jamieson *et al*. (1989, 1990) and Tucker (2011), the rocks in the map were subdivided into several units (Fig. 2). As defined by Jamieson *et al*. (1989, 1990) and modified by Barr *et al*. (1992) and Tucker (2011), the metamorphic rocks include the Jumping Brook Metamorphic Suite (JBMS), consisting of the Faribault Brook metavolcanic rocks, Barren Brook schist, Dauphinee Brook schist, Corney Brook schist, Fishing Cove River schist, Rocky Brook conglomerate and George Brook amphibolite. New mapping also better defined a previously unnamed metamorphic unit to the south, here termed the Stewart Brook Formation. These units have been deformed and regionally metamorphosed to varying degrees, generally ranging from greenschist facies (chloritoid-biotite grade) in the eastern and southern parts of the area to amphibolite facies (kyanite grade) in the northeastern part.

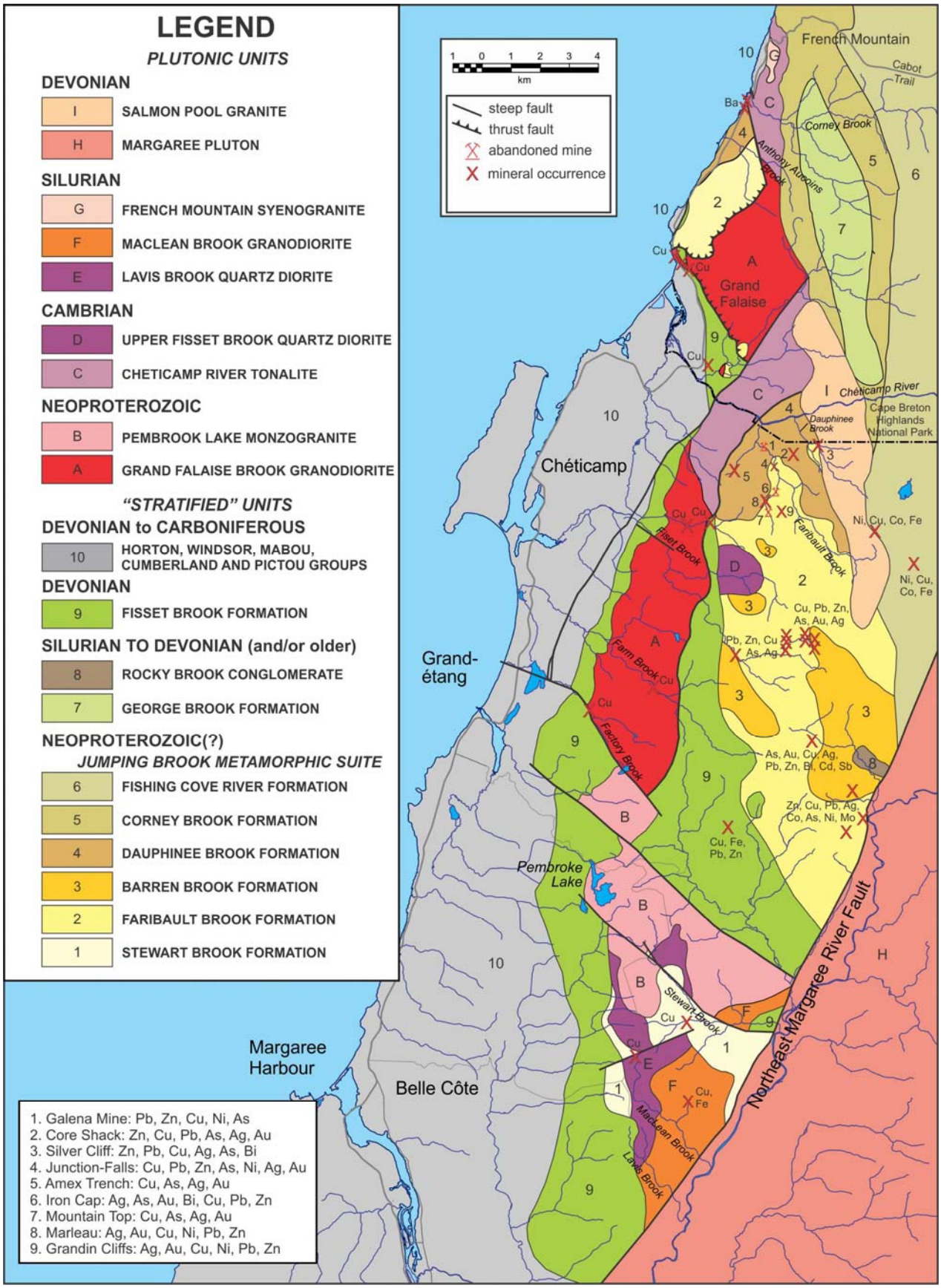
These units are apparently intruded by a suite of Late Neoproterozoic to Silurian plutons (previously included in the Neoproterozoic Chéticamp Pluton) and the Devonian Margaree and Salmon Pool plutons, although intrusive relations cannot everywhere be demonstrated (Slaman, 2015). Along the eastern and southern flanks of the highlands the older units are overlain or in faulted contact with volcanic and sedimentary rocks of the Devonian to Carboniferous Fisset Brook Formation and the Carboniferous Horton, Windsor, Mabou, Cumberland and Pictou groups (Giles *et al*., 1997a, b).

All these units were recognized during the present study and their names have generally been retained; however, Slaman *et al*. (2014) tentatively assigned many of the units in the JBMS to formations, and their terminology is adopted in this report.

Jumping Brook Metamorphic Suite

In this report only the Stewart Brook, Faribault Brook, Barren Brook and Dauphinee Brook formations (Slaman *et al*., 2014) of the JBMS are described. Due to difficult access and time

Figure 2. Geological map of the study area compiled from this study, Jamieson *et al*. (1989), Currie (1987), Lynch and Tremblay (1992), Giles *et al*. (1997a, b) and Tucker (2011). Main mines and mineral occurrences in the Faribault Brook area shown by numbers in legend.


LEGEND
PLUTONIC UNITS
DEVONIAN
I SALMON POOL GRANITE
H MARGAREE PLUTON
SILURIAN
G FRENCH MOUNTAIN SYENOGRANITE
F MACLEAN BROOK GRANODIORITE
E LAVIS BROOK QUARTZ DIORITE
CAMBRIAN
D UPPER FISSET BROOK QUARTZ DIORITE
C CHETICAMP RIVER TONALITE
NEOPROTEROZOIC
B PEMBROOK LAKE MONZOGRANITE
A GRAND FALAISE BROOK GRANODIORITE
"STRATIFIED" UNITS
DEVONIAN to CARBONIFEROUS
10 HORTON, WINDSOR, MABOU, CUMBERLAND AND PICTOU GROUPS
DEVONIAN
9 FISSET BROOK FORMATION
SILURIAN TO DEVONIAN (and/or older)
8 ROCKY BROOK CONGLOMERATE
7 GEORGE BROOK FORMATION
NEOPROTEROZOIC(?)
JUMPING BROOK METAMORPHIC SUITE
6 FISHING COVE RIVER FORMATION
5 CORNEY BROOK FORMATION
4 DAUPHINEE BROOK FORMATION
3 BARREN BROOK FORMATION
2 FARIBAULT BROOK FORMATION
1 STEWART BROOK FORMATION
1 0 1 2 3 4
km
steep fault
thrust fault
abandoned mine
mineral occurrence
French Mountain
Cabot Trail
Corney Brook
Anthony Anoins Brook
Grand Falaise
Chéticamp River
Cape Breton Highlands National Park
Dauphinee Brook
Chéticamp
Fisset Brook
Farbault Brook
Farm Brook
Factory Brook
Grand-étang
Pembroke Lake
Stewart Brook
Maclean Brook
Lavis Brook
Northeast Margaree River Fault
Margaree Harbour
Belle Côte
Ni, Cu, Co, Fe
Cu, Pb, Zn, As, Au, Ag
Pb, Zn, Cu As, Ag
As, Au, Cu, Ag, Pb, Zn, Bi, Cd, Sb
Zn, Cu, Pb, Ag, Co, As, Ni, Mo
Cu, Fe, Pb, Zn
Cu, Fe
1. Galena Mine: Pb, Zn, Cu, Ni, As
2. Core Shack: Zn, Cu, Pb, As, Ag, Au
3. Silver Cliff: Zn, Pb, Cu, Ag, As, Bi
4. Junction-Falls: Cu, Pb, Zn, As, Ni, Ag, Au
5. Amex Trench: Cu, As, Ag, Au
6. Iron Cap: Ag, As, Au, Bi, Cu, Pb, Zn
7. Mountain Top: Cu, As, Ag, Au
8. Marleau: Ag, Au, Cu, Ni, Pb, Zn
9. Grandin Cliffs: Ag, Au, Cu, Ni, Pb, Zn

constraints, only limited mapping was done in the Corney Brook and Fishing Cove River formations, Rocky Brook conglomerate and George Brook amphibolites, and hence descriptions of these units are not included here.

Stewart Brook Formation

The Stewart Brook Formation is a new name proposed by Slaman *et al*. (2014) for an isolated metasedimentary unit in the southern part of the map area. Although not physically connected, it is tentatively assigned to the JBMS. The formation is best exposed in Stewart Brook and its southern tributaries and in the upper parts of brooks and streams along the eastern flank of the highlands (Fig.2). The formation also crops out along parts of the Belle Côte Road and related logging roads in the south.

Barr *et al*. (1992) recognized the metasedimentary character of the unit and mapped it as an undivided Hadrynian gneissic package. During the 1992-1995 NATMAP program, Lynch and Lafrance (1996) mapped the same unit as a mixture of Devonian mylonitic gneiss, cataclasite and breccia. Our mapping has shown that the main western part of the unit consists of pale grey to grey to pale green, well laminated to thinly bedded metasiltstone and phyllitic quartzo-feldspathic sandstone, and rare quartzite. Hornfelsic textures with porphyroblasts of biotite and cordierite are present close to contacts with Silurian Lavis Brook and MacLean Brook plutons (previously included in the Neoproterozoic Chéticamp Pluton) (Slaman, 2015). No mylonitic or cataclastic textures were noted in this area.

On the western flank of the highlands this unit is coarser grained, muscovite-rich, quartzo-feldspathic schist and gneiss. It contains abundant pink, muscovite-rich pegmatite and aplite sills that are commonly boudinaged parallel to the foliation. Black, unfoliated, medium-grained massive gabbroic dykes and sills are rare and display features similar to dykes elsewhere known to be related to the Devonian Fisset Brook Formation (Barr and Peterson, 1998). The adjacent dioritic rocks of the Lavis Brook pluton (previously part of the Chéticamp Pluton) to the east are protomylonitic, suggesting that this contact is a major ductile shear zone incorporating all the schist and gneiss. This package may be the mylonite unit of Lynch and Lafrance (1996); however, on their map this area is included with the dioritic phase of the Chéticamp Pluton. To the west undeformed rocks of the Fisset Brook Formation overlie the schist and gneiss.

Faribault Brook Formation

The Faribault Brook Formation is the largest unit in the JBMS and is best exposed in the upper part of Faribault Brook and its tributaries and in the central part of Dauphinee Brook. In the central and southern parts of the study area, the formation is poorly exposed and crops out mainly along Belle Côte Road and in brooks draining to the west, south and east of the highland plateau area (Fig. 2). The formation also crops out in the hills north of Grand Falaise in the Cape Breton Highlands National Park.

The Faribault Brook Formation is dominantly a mafic metavolcanic package (Fig. 3a) with less abundant intermediate and felsic metavolcanic rocks and minor metasedimentary rocks. Many of the mafic metavolcanic rocks range from massive, thick (up to 4 m wide) amphibolitic layers with relict vesicles now filled with chlorite; the amphibolitic layers locally display deformed pillow structures (e.g. Connors, 1986; Tucker, 2011; Slaman *et al*., 2014). These are interpreted to represent basaltic flows, some of which were subaqueous. Associated with the metabasalt are well layered, fine- to medium-grained, variably textured amphilolite, which are interpreted to represent mafic crystal to crystal-lithic tuff. Many of these rocks have a subhorizontal phyllitic (chlorite) foliation parallel to banding. In some outcrops, the mafic metavolcanic rocks are porphyroblastic with large rectangular amphibole crystals up to 2 cm in length. As seen in drill core, the mafic rocks are mostly fine- to medium-grained, and light to dark green with some black/ brown and yellow depending on alteration. In the area north of Grand Falaise, the Faribault Brook Formation is less metamorphosed and consists of light green to grey, well layered, mafic crystal to crystal-lithic metatuff. Although a strong subhorizontal cleavage is present, the original volcanic textures are still locally preserved.

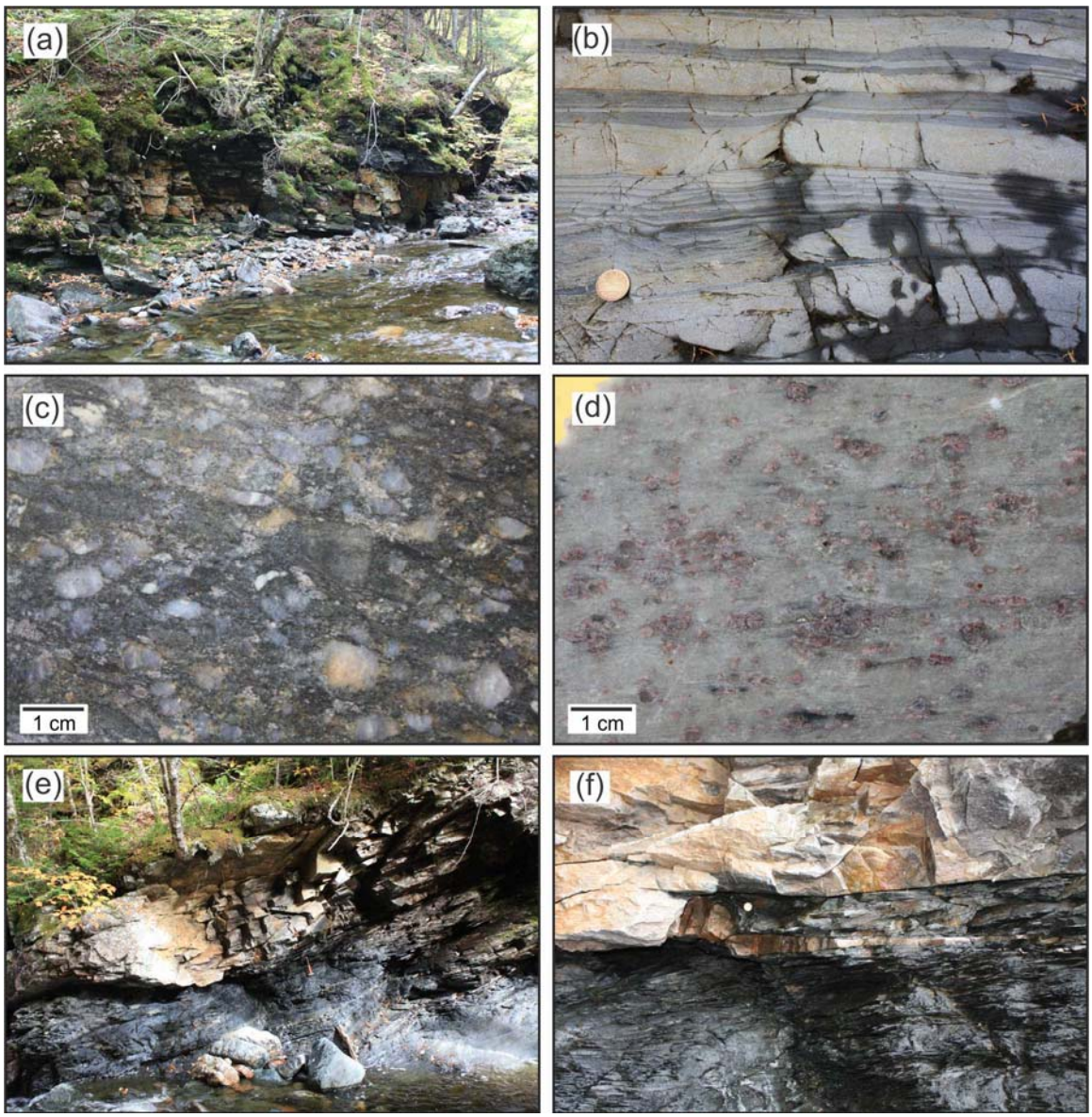


Figure 3. (a) Outcrop of subhorizonal metabasalt with a rust-brown amphibolite sill interpreted to be part of the Faribault Brook Formation. Hammer is 24 cm long. (b) Well bedded metawacke (dark grey) and re-worked crystal tuff (pale grey) in the Dauphinee Brook Formation. Tuff layers display graded bedding. Cross-lamination to the upper right of one dollar coin. (c) Slabbed surface of metaconglomerate with blue quartz clast. (d) Slabbed surface of muscovite-quartz-garnet schist in Dauphinee Brook Formation from Galena Mine adit. (e) Outcrop of pale pink foliated granite sheet in slate from the upper part of Dauphinee Brook Formation. Foliation and bedding dip shallowly to the left. Hammer is 24 cm long. (f) Close-up of area to the left of the hammer in photograph 'e' showing offshoot of granite into slate. One dollar coin for scale.

Minor intermediate and felsic metavolcanic rocks (now phyllite) are interlayered with the mafic rocks in some outcrops and in drill core (Tucker, 2011). These rocks are more quartzofeldspathic but still contain significant amounts of metamorphic amphibole and biotite. Some intermediate metatuff samples contain garnet and abundant epidote and may have a more volcaniclastic protolith.

Metasedimentary rocks in the Faribault Brook Formation include metawacke (locally conglomeratic with pebble-sized quartz clasts), quartzite, metasiltstone, biotite phyllite/schist, and quartz-chlorite phyllite/schist. Many of these metasedimentary rocks are more common in drill core than at surface. Quartzite and metawacke were seen at both the Marleau and Grandin Cliffs

showings, as well as in drill core. At Marleau and Grandin Cliffs the quartzite appears to form a stratigraphic layer, 0.5-2 m in thickness, within a muscovite-quartz-feldspar phyllite/schist. Based on its mineralogy and chemistry, Tucker (2011) inferred that the protolith of the muscovite-quartz-feldspar phyllite/schist was a silicified felsic volcanic rock, but based on its association with quartzite, it could equally have been a quartzofeldspathic sedimentary rock. Massive, homogeneous amphibolite layers occur throughout the sequence and may represent synchronous mafic sills and dykes.

The thickest section in drill core is approximately 180 m (drill hole #1 – C-1), but that thickness is a minimum as the base of the unit was not reached in any of the drill holes and the nature of the underlying "basement" is unknown (Tucker, 2011).

Barren Brook Formation

Limited mapping in the Barren Brook Formation south of Faribault Brook was completed during the summer of 2014; therefore, much of the distribution of the formation in the southern part of the map area (Fig. 2) is modified after previous work by Jamieson *et al*. (1989) and Tucker (2011). Much of what is shown as Barren Brook Formation by Tucker (2011) west of Faribault Brook is now included in Dauphinee Brook Formation (Slaman *et al*., 2014). The formation is interpreted to conformably overly the Faribault Brook Formation; based on drill core observation, it has an estimated thickness between 50 to 300 m (Tucker, 2011).

The Barren Brook Formation consists mostly of volcanogenic metawacke to pebbly metawacke interbedded with fine- to coarse-grained phyllite/schist. According to Jamieson *et al*. (1989), a characteristic feature of this formation is the presence of blue "quartz eyes" in the pebbly metawacke and metasandstone, a feature also recognized during this study. Primary sedimentary features, such as graded bedding, were observed locally. Rounded granitic clasts containing quartz, alkali feldspar and plagioclase as well as separate clasts of quartzite, feldspar and quartz are present in the coarser metawacke layers (Tucker 2011). Their source is uncertain.

The more schistose samples from the formation are quartz-mica-garnet schist that range from fine to coarse grained and contain quartz, chlorite, biotite, garnet and plagioclase. In lower metamorphic grade rocks, chloritoid was recognized, and at higher grades trace amounts of sillimanite were observed (Tucker, 2011).

Dauphinee Brook Formation

The Dauphinee Brook Formation is interpreted to be the uppermost unit of the Jumping Brook Metamorphic Suite and is well exposed in lower Faribault Brook and hills to the east and west. It is also exposed in the hills south of Anthony Aucoins Brook in the Cape Breton Highlands National Park (Fig. 2). It is present in the numerous drill holes south of Chéticamp River and has a minimum thickness of 50 m based on these drill holes (Tucker, 2011). Tucker (2011) mapped the Dauphinee Brook Formation as overlying the Barren Brook Formation and, based on drill core, showed that in places the formation unconformably overlies the Faribault Brook Formation. In this interpretation, Tucker (2011) assumed that the Barren Brook Formation pinched out to the south. Slaman *et al*. (2014) showed the Dauphinee Brook Formation conformably overlying the Faribault Brook Formation, an interpretation we adopt (see below).

The most common rock types of the Dauphine Brook Formation are slate and metasiltstone that are phyllite or schist at higher metamorphic grades, metasandstone to quartzite, metawacke, and pebbly metaconglomerate. We also recognize the presence of minor mafic, intermediate and felsic crystal to crystal-lithic metatuff. These tuffaceous rocks were recognized by Jamieson *et al*. (1989) but included with the Faribault Brook Formation.

Near the lower parts of the Dauphine Brook Formation, grey metawacke is interlayered with reworked feldspar crystal tuff, both of which display relict cross-laminations and graded bedding (Fig. 3b). These units are associated with pebbly metawacke and metasandstone beds that contain blue quartz eyes (Fig. 3c), a characteristic more typical of the Barrens Brook Formation (cf. Jamieson *et al*. 1989). However, here the pebbly

metawacke is locally associated with metavolcanic rocks, which are not observed in the Barrens Brook Formation. Based on the distribution and position in the stratigraphy of the blue quartz-eye beds (always above the Faribault Brook Formation), we consider these beds as a marker horizon; therefore, the Barren Brook Formation maybe the lateral facies equivalent of the Dauphine Brook Formation. This interpretation reconciles the stratigraphic complexities noted by Jamieson *et al*. (1989) and Tucker (2011).

The formation becomes more pelitic towards the stratigraphic top which has abundant metasiltstone and slate and less metavolcanic material. The rocks are typically dark to light grey, fine grained and crenulated. Compositional layering and graded bedding are locally well preserved. These observations led Jamieson *et al*. (1989), Lynch and Tremblay (1992) and Tucker (2011) to speculate a turbiditic origin for the formation, at least for the upper part. At higher metamorphic grades the rocks are pyllitic and schistose and contain muscovite, biotite, quartz, lithic fragments, chlorite, epidote and feldspar. Garnet is locally abundant.

Very distinctive pale muscovite-garnet schist with quartz eyes occurs in two locations in the formation. One occurrence is in Faribault Brook at the Galena Mine where it forms a two-metre-wide bed that can be traced downstream for over 200 m, and the other at the Core Shack occurrence farther to the east (Fig. 2). In places it is boudinaged parallel to the foliation, and along strike it pinches out. It consists of muscovite, biotite, quartz, garnet and saussuritized feldspar, and the foliation is defined by muscovite and biotite that wraps around poikiloblastic garnet (Fig. 3d). Garnet components are mainly almandine and spessartine plus a small amount of pyrope (Tucker, 2011). The protolith is unclear. Lin *et al*. (2007) and Tucker (2011) favoured an intrusive felsic porphyry origin. Because the schist is associated with known sulphide mineralization, has an unusually high Al content (Tucker, 2011) and looks texturally similar to the blue quartz-eye metawacke, we interpret that this rock was once a hydrothermally altered metawacke prior to metamorphism.

Pale pink to grey, fine- to medium-grained granitic sheets are locally preserved in the formation (Fig. 3e). They range in thickness from 1 m to 3 m in thickness. In spite of being foliated, boudinaged and metamorphosed; cross-cutting relations are locally preserved (Fig. 3f).

Plutonic Units

Prior to the study by Slaman (2015), the Chéticamp Pluton (Barr *et al*., 1986) was considered to form a single elongate body along the western part of the map (Fig. 2) and based on detailed mapping in 2014, divided into six mappable units ranging from diorite to syenogranite (Slaman *et al*., 2014; Slaman, 2015). Many of the plutons are in faulted contact with the JBMS; however, some contacts in the southern part of the area appear to be intrusive based on the presence of a contact metamorphic aureole in the adjacent rocks of the Stewart Brook Formation. Some of the plutons are also in faulted contact with the Fisset Brook Formation, but locally an unconformable relationship is preserved (Barr and Peterson, 1998; Slaman *et al*., 2014). Based on the M.Sc. thesis work by the second author (Slaman, 2015), the former Chéticamp Pluton has been shown to consist of three units: Grand Falaise granodiorite, Pembroke Lake monzogranite and Chéticamp River tonalite. The Chéticamp River tonalite is Cambrian (ca. 493 Ma) and unrelated to the older (ca. 567 Ma) Grand Falaise and Pembroke Lake units. The MacLean Brook granodiorite and Lavis Brook quartz diorite, located south of the Pembroke Lake monzogranite and previously assumed to be Devonian and Neoproterozoic, respectively, are both Early Silurian (ca. 440 Ma) and constitute a cogenetic bimodal suite. The undated Upper Fisset Brook quartz diorite may be related to the Chéticamp River tonalite, and both likely intruded the Jumping Brook Metamorphic Suite. A small area of syenogranite (~419 Ma) at French Mountain is the youngest unit in the former Cheticamp Pluton (Fig. 2) (Slaman, 2015). A detailed study of the petrography, lithogeochemistry and age of the plutons is available in Slaman (2015), and hence these data are not presented in this report.

Younger Plutonic Units

Several younger plutonic units are present in the study area but were not included in the present

work; brief descriptions presented here are based on the references cited. The Margaree Pluton is a large Devonian pluton located east of the Jumping Brook Metamorphic Suite (Fig. 2). It consists of coarse-grained, megacrystic biotite-amphibole monzogranite (Barr *et al.*, 1992; Horne *et al.*, 2003) and is in faulted contact with the Jumping Brook Metamorphic Suite. The Salmon Pool Granite is a smaller Devonian pluton that intrudes the eastern margin of the Jumping Brook Metamorphic Suite (Fig. 2). The granite is pink and commonly fine grained with porphyritic biotite to megacrystic plagioclase and consists of quartz, plagioclase, K-feldspar, biotite and minor amounts of amphibole (Jamieson *et al*., 1986). Along the eastern margin, grey fine-grained diorite is co-mingled with granite. The granite is locally deformed close to faults and displays a well developed foliation.

Younger Volcanic and Sedimentary Units

The Devonian Fisset Brook Formation occurs on both the eastern and western sides of the plutonic belt and to the south of the Jumping Brook Metamorphic Suite (Fig. 2). It unconformably overlies the older units, although many of the contacts are now faults (Barr and Peterson, 1998). The formation consists of interlayered volcanic and sedimentary rocks (Kelley and Mackasey, 1965; Blanchard *et al*., 1984; Barr and Peterson, 1998; Slaman *et al*., 2014). Rhyolite tuff and flows occur near the top of the formation and have yielded U-Pb ages of 371 ± 2 Ma (western belt) and 374 +6/-3 (eastern belt) (Dunning *et al*., 2002).

Unmetamorphosed mafic sills and dykes with well developed chill margins in the JBMS and Chéticamp Pluton *are* interpreted to be related to the Fisset Brook Formation. Carboniferous sedimentary rocks occur at the western edge of the map area and include the Horton, Windsor, Mabou, Cumberland and Pictou groups (Giles *et al*. 1997a, b). They were not examined in the present study.

Geochemistry

Tucker (2011) analyzed mafic and felsic samples with igneous protoliths from the JBMS and incorporated additional data from Jamieson *et al*. (1989), Currie (1987) and Barr *et al*. (1986). Whole-rock data from this study were obtained from many of the plutonic units and supplemented with additional samples from Barr *et al*. (1986). Data from Slaman (2015) is not incorporated in this report.

Using Zr and Ti plotted against SiO_2, the mafic samples plot in the subalkalic basalt field (Fig. 4a). The subalkalic character is also shown in the felsic samples, which plot mostly in the rhyodacite-dacite and rhyolite fields (Fig. 4a). On the Th-Hf-Nb discrimination diagram, the mafic samples plot in the island-arc tholeiite field because of their low Nb relative to Th and Hf (Fig. 4b). On the AFM plot the samples appear tholeiitic (Fig. 4c).

On a chondrite-normalized REE diagram, the metabasalt sample patterns are mostly parallel to one another and show strong light-REE depletion (Fig. 4d). Only one sample shows a significant negative Eu anomaly, indicative of plagioclase fractionation. The light-REE depleted pattern displayed by these samples is typical of mid-ocean ridge basalt and generally attributed to derivation of the parent magmas from a depleted mantle source (e.g. Winter, 2010).

Geochemical classification based on a normative Q'-ANOR diagram (Fig. 5a) shows the plutonic units ranging from diorite to granodiorite to alkali-feldspar granite, based on the analyzed samples. Combined with the AFM diagram (Fig. 5b), the data indicate calc-alkalic character for all the plutons. On the tectonic setting discrimination diagram for granitoid rocks (Fig. 5c), all samples plot in the volcanic-arc field.

Mafic samples from the Faribault Brook Formation have chemical characteristics indicative of island-arc tholeiite to N-MORB affinity. The chemical characteristics, combined with the locally observed pillows and association with turbiditic sediments, are most likely indicative of a back-arc basin setting whereas the plutonic units have arc-like characteristics.

Age

The age of the JBMS and its contact relations with the adjacent plutonic units have been long-standing

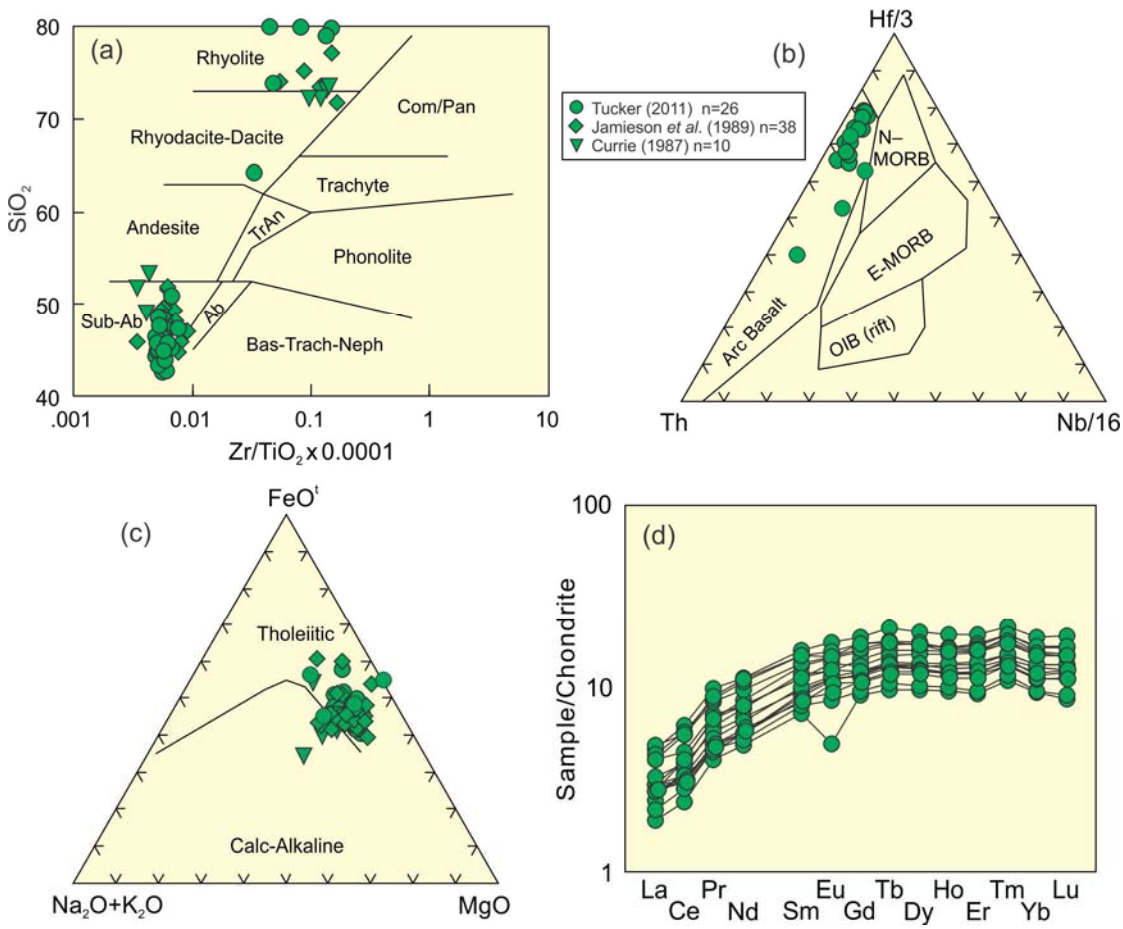


Figure 4. Chemical discrimination diagrams for mafic and felsic samples from the JBMS unit. (a) Plot of SiO_2 against Zr/TiO_2 after Winchester and Floyd (1977). (b) Plot of Th – Hf – Nb after Wood (1980). (c) Ternary plot of Na_2O+K_2O – FeO^t – MgO with tholeiitic/calc-alkalic dividing line from Irvine and Baragar (1971). (d) Chondrite-normalized rare-earth element data for metabasalt samples from the Faribault Brook Formation. Chondrite-normalizing values are from Sun and McDonough (1989).

problems ever since zircon in the former Chéticamp Pluton (Pembrook Lake monzogranite) was dated at 550±8 Ma (Jamieson *et al*., 1986). Most workers have considered the pluton to be older than the JBMS (e.g. Currie, 1987; Jamieson *et al*., 1989, 1990), based in part on Silurian ages obtained from volcanic units elsewhere in the Aspy terrane (e.g. Barr and Jamieson, 1991), but others (e.g. Woods, 1986) interpreted that the pluton intruded the JBMS. However, now that the former Cheticamp Pluton is shown to consist of Late Neoproterozoic (ca. 567 Ma), Cambrian (ca. 490 Ma), Silurian (ca. 440 Ma) and Devonian (ca. 390 Ma) plutons, all these interpretations are viable (Slaman, 2015).

Three U-Pb ages from the Dauphinee Brook Formation were reported by Lin *et al*. (2007). Zircon ages of 551 ± 0.9 and 546 ± 2 Ma were obtained from metatuff and metapsammite, respectively. However, a poorly constrained zircon age of 420 ± 7 Ma was obtained from a "quartz porphyry" sample collected approximately 100 m downstream from the Galena Mine (Lin *et al*., 2007). It is unclear if the dated sample is from the blue quartz metawacke or the highly altered muscovite-quartz-garnet schist, both of which crop out at these locations. Preliminary ICP-MS U-Pb dating on detrital zircons from a blue quartz metasandstone from elsewhere in the Dauphinee Brook Formation, yielded major age clusters at 630-590 Ma and 560-530 Ma. The younger cluster of ages is slightly younger but similar to that of the Pembrook Lake and Grand Falaise plutons and suggests a Late Neoproterozoic age for both the JBMS and the older plutons.

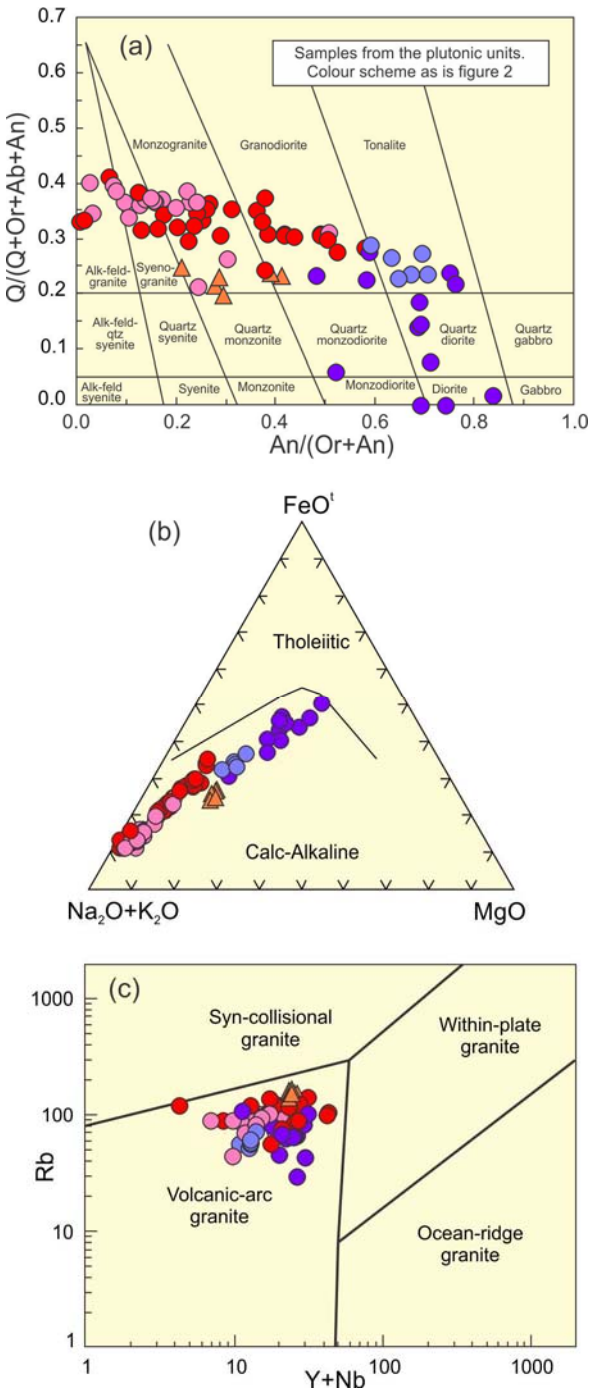


Figure 5. Chemical discrimination diagrams for samples from the plutonic units. (a) Plot of CIPW normative An/(Or+Ab) against Q/(Q+Or+Ab+An) for samples from the plutonic units. Fields are from Streckeisen and Le Maitre (1979). Normative mineralogy was calculated setting Fe_2O_3 at 0.15 of the total Fe. (b) Ternary plot of Na_2O+K_2O – FeO^t – MgO with tholeiitic/calc-alkalic dividing line from Irvine and Baragar (1971). (c) Rb-Y+Nb tectonic setting discrimination diagrams for granitic rocks from Pearce *et al.* (1984).

Economic Geology

An occurrence of galena was found in schist in the lower part of Faribault Brook in 1897 (Alcock, 1930), and since then the region has been explored for its numerous base metal occurrences (Fig. 2) and locally mined (Fig. 6a, b). Mapping confirmed that most of the mineralization occurs near the contact between the Faribault Brook and overlying Dauphinee Brook formations. The most abundant type of mineralization consists of pyrite, pyrrhotite, chalcopyrite and arsenopyrite, whereas some deposits contain galena, sphalerite (Fig. 6c) and gold.

The mineralized layers and pods are 3-5 cm thick, 5-30 cm long, and are concordant with the main schistosity. They are commonly folded and strongly boudinaged, confirming a pre-metamorphic/deformational origin (e.g. Lynch and Mengel, 1995). A younger set of sulphide-bearing, deformed quartz veins were recognized this summer at many of the showings, suggesting a later remobilization of quartz and sulphide minerals.

In addition, mapping has also delineated several Cu-bearing shear zones, fractures and carbonate veins in many of the plutonic units and Fisset Brook Formation. Numerous barite veins are associated with faults along the western margin of the Chéticamp Pluton.

Regional Correlations

Late Neoproterozoic rocks with similarities to the Jumping Brook Metamorphic Suite occur in both Newfoundland and New Brunswick (Fig. 7). In central Newfoundland, the Crippleback Lake intrusive suite is dated at 563 ± 2 Ma (Evans *et al.*, 1990) and consists of three plutons: Crippleback Lake, Valentine Lake and Lemottes Lake (Rogers *et al.*, 2006). These plutons intruded the Sandy Brook Group but have been suggested to be co-magmatic with that suite (Rogers *et al.*, 2006). The Crippleback Lake intrusive suite is interpreted to have formed in a continental arc, as did the Chéticamp Pluton. The Sandy Brook Group consists of pillowed and massive basalts, mafic tuffs, cryptocrystalline andesite flows and cherty, quartz-phyric, high-silica rhyolite (Rogers *et al.*, 2006). These units that have similarities to the

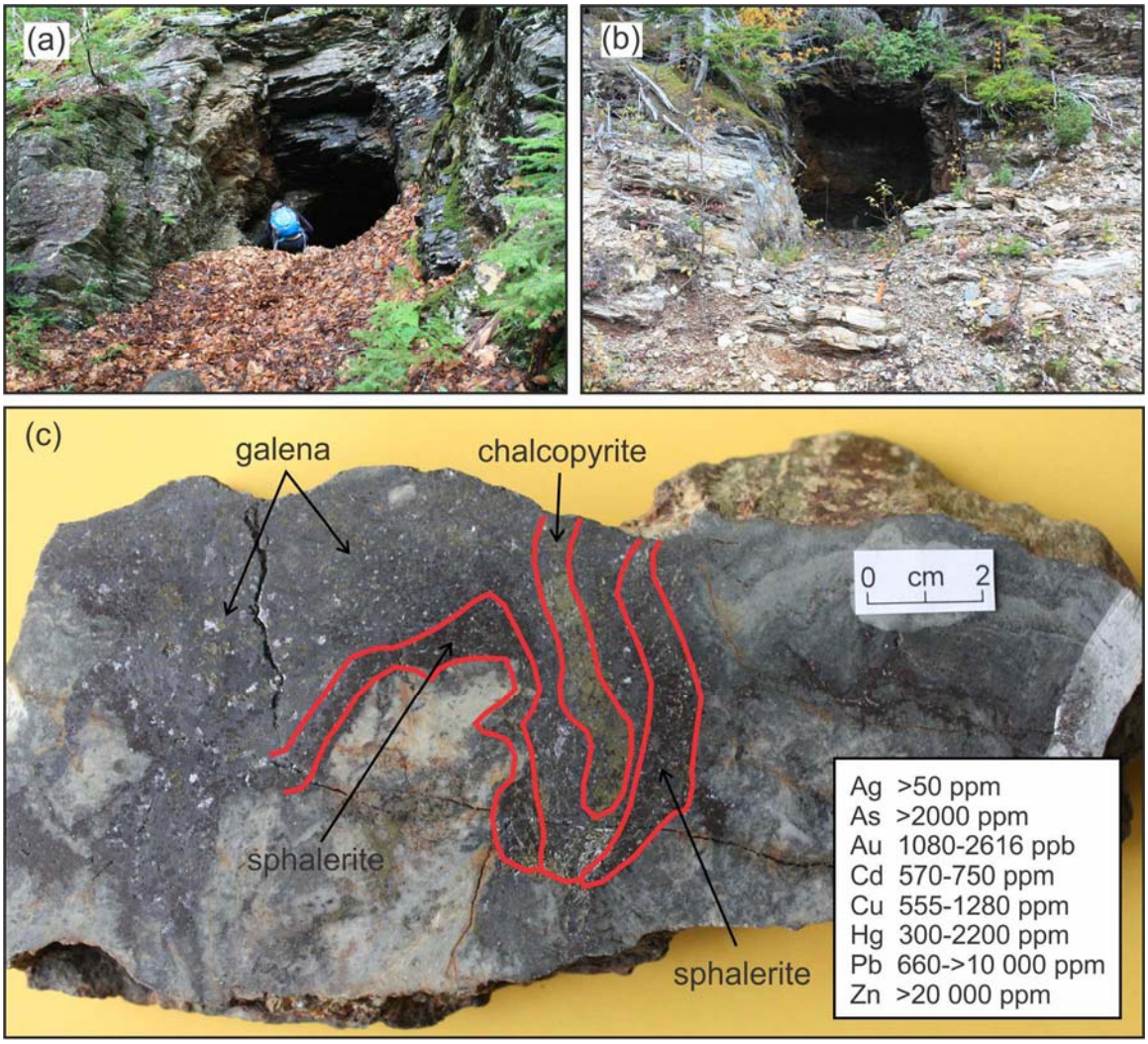


Figure 6. (a) Photograph of Galena Mine adit in Dauphinee Brook Formation. (b) Photograph of Mountain Top Mine adit in Faribault Brook Formation. (c) Cut slab of mineralized sample from the Galena Mine dump showing folded layers of sphalerite, chalcopyrite and galena. Rock sample courtesy of G. DeMont. Assay values from grab samples in and around the Galena Mine showing. Mineral occurrence number K10-016 in Nova Scotia Department of Natural Resources (2008).

Faribault Brook Formation and the basaltic units in the Sandy Brook Group have arc characteristics and are considered to be island-arc tholeiites (Rogers *et al*., 2006). This possible correlation is important because these rocks in Newfoundland host the Burnt Pond volcanic massive sulpide (VMS) deposit (Squires and Moore, 2004).

In New Brunswick the New River terrane (Fig. 7) occupies a similar tectonic position as the western part of the Aspy terrane. Although similar in age, these rocks differ from the JBMS in that they have not been regionally metamorphosed and have a much higher proportion of volcanic components.

The New River terrane also includes ca. 620 Ma rocks (Johnson *et al*., 2009) that may correlate with rocks of similar age in the Mabou Highlands and not the JBMS.

More detailed geological mapping and geochronology are needed in order to resolve with certainty the relationships among the rock units in the Faribault Brook area. In particular felsic metavolcanic units in the Jumping Brook Metamorphic Suite should be targets for additional U-Pb geochronology to confirm the Neoproterozoic age suggested by this study. Additional geochemical and isotopic analyses are required to

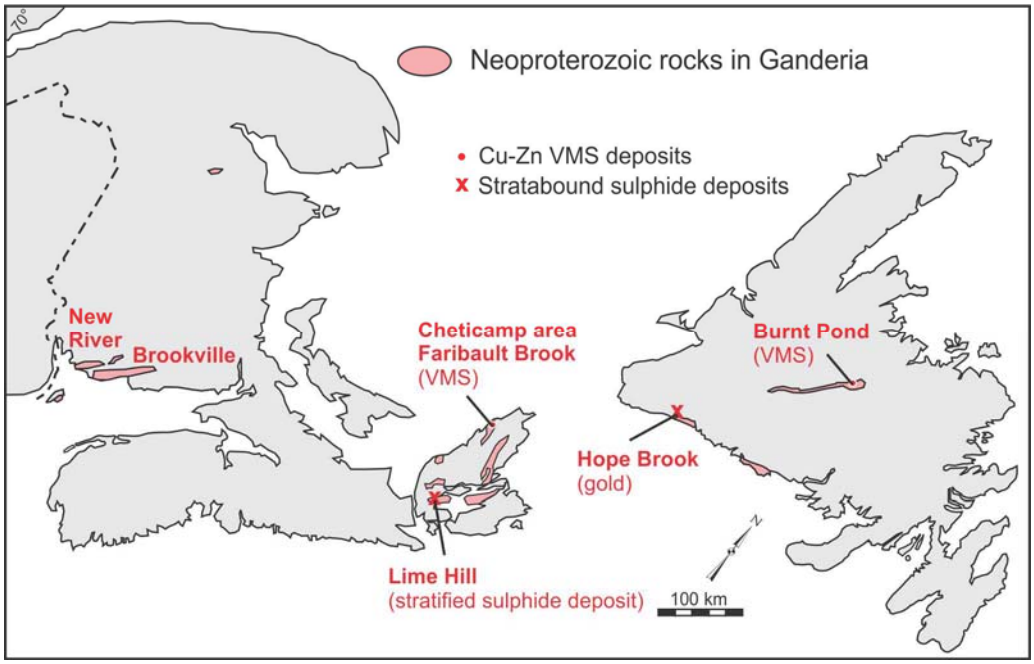


Figure 7. Map of the Atlantic Provinces showing Neoproterozoic VMS deposits in Ganderia. Modified from van Staal (2007).

better understand the tectonic setting of the volcanic and sedimentary units and to aid in regional correlations to formations elsewhere in Atlantic Canada.

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